FIELD MEASUREMENTS OF SEDIMENT TRANSPORT PROCESSES IN STRATAFORM

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LONG-TERM GOALS

The overall long-term goal of STRATAFORM is to advance our understanding of the development of stratigraphic sequences on continental shelves and slopes. An essential part of this understanding comes from direct measurements of the response of bottom and suspended sediment to oceanic forcing in the study areas. In this project our specific long-term goal is to obtain high quality time-series measurements of flows and sediment parameters in the bottom boundary layer on the continental shelf off northern California, and to utilize these data to derive estimates of sediment resuspension and flux. Additionally the time-series data will be used in conjunction with measurements of bed roughness, local and regional-scale sediment size distribution studies, and density stratification to validate and provide inputs for sediment transport models.

SCIENTIFIC OBJECTIVES

+ One primary objective is to obtain high-quality, time-series measurements of wave, current and suspended sediment concentrations in the bottom boundary layer on the continental shelf during specific experimental periods using the instrumented Geoprobe tripod. The measurements are taken as part of an array of instrumented tripods and moorings.

+ A second objective is to analyze the tripod data for bottom boundary layer structure (velocity profiles, bottom stress, roughness), suspended sediment profiles, and local morphological changes of the bed surface. These analyses will be accomplished in conjunction with the analyses of other bottom boundary layer measurements.

+ A third objective is to use the tripod data to improve sediment transport and stratigraphic models.

+ A final objective, that is being coordinated and carried out by David Drake at USGS, is to provide high quality information on grain size distributions from near-surface sediment samples obtained with box cores, and in short subcores that sample the upper 20 cm of the sediment bed. The textural characteristics of flood and storm deposits at various sites on the shelf will provide direct input to guide and test sediment transport models. In addition, an intensive program to determine spatial correlation length scales is now underway.

APPROACH

The area selected for the field program is the shelf and upper slope north of the Eel River mouth off northern California. In water depths greater than about 40 m this region is characterized by rather simple bathymetry. Based on samples collected in box cores and from side-scan sonar records, the surface deposits in this area are sandy on the inner shelf (to depths of about 50 m) and grade into mud in deeper water (Bouchard and Borgeld, 1988; Wheatcroft, et al., 1996).

The experimental plan for the winter of 1996-1997 was to deploy the Geoprobe tripod within an array of moorings and instrumented bottom systems on the shelf north of the mouth of the Eel River. This array would be used to measure the flows and suspended sediment concentrations associated with fairweather, flood and storm periods. One goal was to determine the sediment flux near the seafloor during active surface plume

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events caused by flood discharge from the Eel River. The direction and duration of these flux episodes will aid our understanding of the development of flood deposits on the shelf and slope.

Sediment samples have been collected for grain size analysis on each of the numerous shelf sea-bed sampling cruises in 1996 and 1997. These samples are presently being analysed to investigate temporal modifications of the major flood layers of 1995 and 1997. In addition, Drake participated in the intensive spatial correlation scale study in July 1997 aboard R/V Melville.

WORK COMPLETED

We deployed the Geoprobe tripod in about 62 m depth (site K-60) for about three months during the winter (Table 1). These measurements provide detailed time-series data to examine local sediment resuspension during the floods, and to measure the magnitudes and directions of near-bottom sediment transport associated with the plumes.

Sediment samples for detailed grain size study were collected on shelf sampling cruises in November 1996, January 1997, May 1997, July 1997 and October 1997. Laboratory analyses are underway.

Drake also prepared laboratory calibration data for the LED transmissometers used on Geoprobe. Finally, Drake participated in the interlaboratory comparison study for grain size analysis methods coordinated by colleagues at Old Dominion University.

Table 1. Measurements obtained in the bottom boundary layer by the GEOPROBE tripod.

	Deployment Information
Location	40^{o} 46.39' N 124^{o} 21.46 W
Depth (m)	62.5
Data Start	0900 PST, Nov. 21, 1996
Data End	0900 PST, Feb. 3, 1997

Parameter (# sensors)	Ht. above bottom (cm)	Sample Interval (s)	# samples each hour
pressure (1)	236	1	1024
current velocity (4)	21, 55, 89, 123	1	1024
light transmissivity (3)	35,101,182	1	1024
optical backscatter (5)	10, 23, 54, 88, 118	1	256
temperature (2)	50, 180	1	1024
		60	60
bed elevation (1)	168	1	60
temperature (CTD) (1)	115	300	12
conductivity (CTD) (1)	115	300	12
depth (CTD) (1)	115	300	12

RESULTS

The Geoprobe tripod provided useful time-series data from each of the sensors listed in Table 1 for the entire period. The low-frequency bottom flow was generally alongshelf toward the NE except during brief periods of 2-3 days following storms, when the currents reversed and flowed toward the SW. The average low frequency bottom flows (at about 1.2 m above bottom) over the entire 74 days of measurements were about 8.2 km/day poleward and about 4.0 km/day offshelf.

The results for the current measurements were in striking contrast to those from last winter (1995-1996) when the net flows over the December-January period were southward and offshelf. During both periods the bottom currents increased markedly toward the NE as low pressure centers (storms) approached the region in response to strong southerly winds. After the storms passed through the region, the winds and currents then typically reversed. During the latest measurements the durations and strengths of the reversals in the bottom flows were reduced from the previous year. The poleward bottom flows which were typical during the winter of 1996-1997 caused increased sediment flux in that direction as compared to the previous year.

In the top panel of Figure 1 the hourly current vectors show the predominance of the poleward flows commencing in early December. During the storm periods of early December and in early and late January the near-bottom flow speeds exceeded 50 cm/s. The largest bottom wave velocities (second panel from top) are about 60 cm/s in early December. The pulses of prolonged high sediment concentration above the bed (third panel from top, Fig. 1) occur during these storm events, and also during considerably less energetic times in mid-December (Dec. 11-14) and in mid-January (Jan. 12-15). The latter increases in near-bottom concentrations are likely associated with advection of material from other locations, particularly from the Eel River to the south.

The sonic altimeter provided hourly data on bed elevation (bottom panel, Fig. 1). The low amplitude (< 5 cm) variations in the bed level were likely caused by small ripples migrating through the measurement area, or they might have been caused, in part, by reflections from a dense near-bed layer of suspended material or bed load. There is a curious peak in bed elevation of about 10-12 cm amplitude on January 3 that lags a time of high wave and current speeds (the highest current speed of 67 cm/s in the entire record occurred on January 1). The suspended sediment concentrations at 23 cm above the bed (bottom panel, Fig. 1) are sustained at exceedingly high levels in excess of 10 g/l prior to this peak in bed elevation. One possible interpretation is that a fluid mud layer developed at this site (or was advected to this location), engulfing the lowest OBS probe (at 10 cm above the bottom; not shown) and saturating the output above 10 g/l. Based on the sonic altimeter record, the fluid mud layer was greater than about 10 cm thick. The fluid mud layer persisted for about 18-20 hours.

If fluid mud did form on this section of the shelf, it would have great implications for the mode and magnitude of sediment transport along and off the shelf. An event in which fluid mud was transported to the Geoprobe tripod, causing extinction of the lowest optical and current sensors was reported in the analysis of similar data from the Amazon prodelta (Cacchione, et al., 1995). Further study of these data and other measurements from nearby sensors to determine the likelihood that fluid mud was formed is underway.

The sediment grain size study has produced important new insights into the deposition and evolution of a major river flood deposit on the Eel shelf (Drake, in press). This work has shown that very fine-grained mud deposited on the middle shelf (70 m water depths) is not removed by subsequent storm events but instead is modified principally by the addition of relatively coarse-grained sediment that is transported from the inner shelf. This finding is in excellent agreement with the tripod results and the "floc-camera" data presented by Sternberg and Ogston (in press, *Marine Geology* volume). The evolution of the flood layer is of particular interest to the sediment transport modeling group. Temporal and spatial variability studies are continuing and they are providing significant insight into the scales of variability to be expected in different shelf settings.

IMPACT ON SCIENCE AND TECHNOLOGY

This project is loaded with novel instrumentation for making measurements within the bottom boundary layer on continental shelves. The high quality, quantitative measurements of bottom currents, waves and sediment characteristics will serve as necessary inputs to sediment transport and stratigraphic models of shelf deposits. The interpretation that fluid mud formed during storm-induced wave and current stresses following a period of high sediment discharge from the Eel River has great implications for the amount of sediment transported on this shelf.

TRANSITIONS

The instrument systems developed under this project have contributed to the development of related systems by other investigators in this and other programs. The ongoing development and testing of the rotating side-scan sonar to be mounted on the Geoprobe tripod, and the upgrade to include microbathymetric measurements using this technology, is underway.

RELATED PROJECTS

This project is closely related to other STRATAFORM projects which are involved measurements of sediment transport. These include projects by R. Sternberg, U. of Washington, by L.D. Wright, VIMS, and by J. Lynch and J. Irish, WHOI. The sediment grain size studies are closely related to the modeling work of Wiberg and Harris, and Swift and others. Sediment textural information is also important to the stratigraphic research of Nittrouer and Wheatcroft and their students Sommerfield, Bentley and Walsh.

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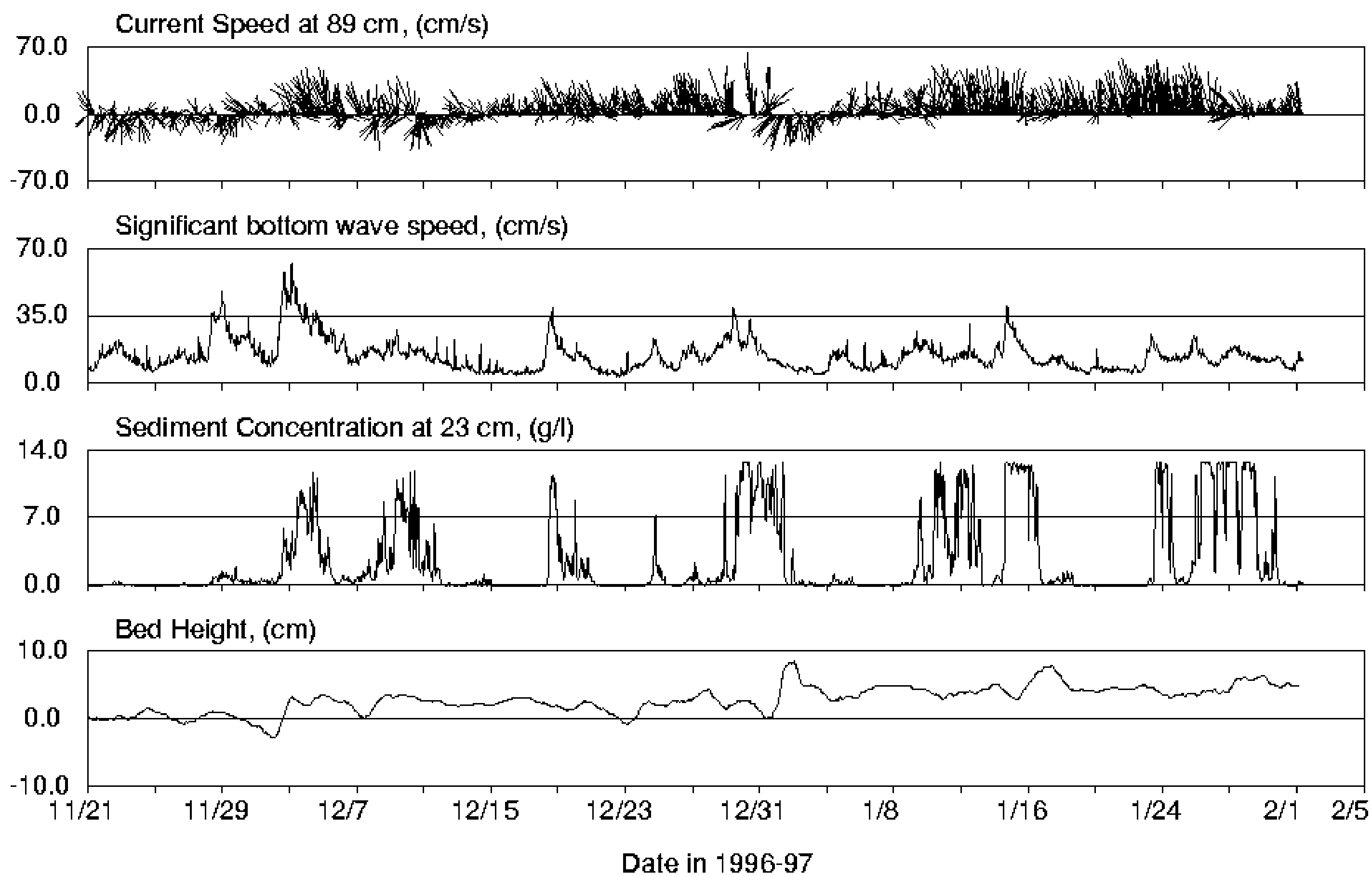

Fig. 1 GEOPROBE tripod data during Strataform. Poleward alongshelf flow is towards the top of the vector diagram.